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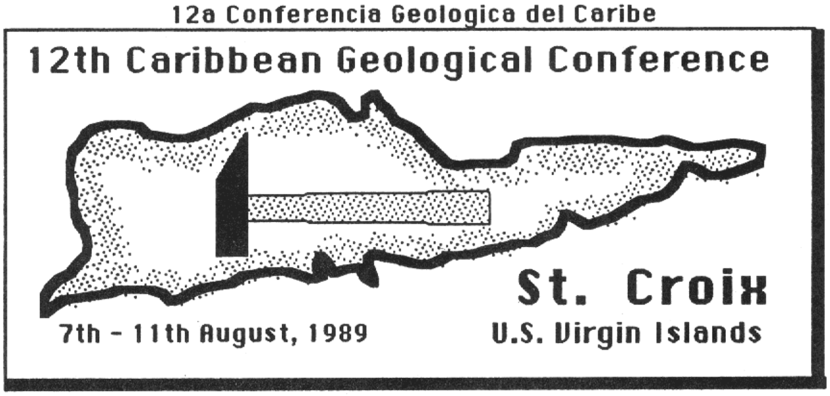

12me Conference Geologique de Caraibes

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CONTRIBUTION OF PALEOMAGNETISM IN THE RELATIONS BETWEEN THE PIEMONTIN AND INTERNAL NAPPES OF THE VENEZUELAN CARIBBEAN CHAIN : SYNTHESIS AND NEW DATA.

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ABSTRACT

The eastward displacement of the Caribbean plate between the two Americas occurs along large transcurrent zones, dextral and sinistral respectively to its south and north boundaries. This particular setting explains the 90° of clockwise rotations shown by the paleomagnetic vectors of the Venezuelan Caribbean mountain chain. In order to define the relations between the Piemontin and internal nappes of the Caribbean chain, a study was undertaken 100 km to the south of Caracas in the Guárico and Cojedes States in 1988. Among the twenty-one drilled sites, two of them are located in the internal nappe of Villa de Cura (in the north), ten in the Piemontin nappe and nine in the autochthonous foreland (in the south).

- In agreement with other paleomagnetic studies, the Villa de Cura nappe shows evidence for a 90° clockwise rotation.
- The Piemontin nappe does not show an overall rotation.
- The results about the foreland indicate a north-south orientation of the paleomagnetic vectors. They are in agreement with the paleomagnetic declinations of the south-american craton and suggest an autochthonous character of the foreland.
- The general north-south orientation of the paleomagnetic vectors deviate near the Guárico and Guaitoco faults (dextral faults).

These results confirm that the Villa de Cura nappe was a north-south oriented island arc, in agreement with the models of Caribbean geodynamic evolution proposed by various authors (Pindell and Dewey, 1982 ; Stephan, 1982 ; Beck, 1986). In contrast, the Piemontin nappe did not rotate and has moved with an orientation similar to its original position. Finally, the autochthonous Oligo-Miocene sandstones, to the south of the Piemontin nappe, show only local rotations near the Guárico and Guaitoco dextral faults.

INTRODUCTION

The Caribbean region is a small lithospheric plate that is moving eastward with respect to the two Americas (Fig. 1). According to Stephan (1982, 1985), Stephan and al. (1985), Beck (1986), its boundaries are formed by :
- in the east, subduction of the Atlantic Plate under the lesser Antilles arc;
- in the west, subduction of the Pacific Plate under Central America;
- in the north, sinistral oblique subduction along the Puorto-Rico trench, with in continuation, the Caiman spreading center in the west. A transform fault zone (Swan, Barlett and Polochic-Motagua) joins the Central America trench to the Tehvantepec Isthmus;
- in the south, a dextral transcurrent zone : the Oca-El Pilar fault system.

Figure 1 shows a summary of the paleomagnetic data of the Caribbean region (Watkins and Cambray, 1971 ; Steinhauser and Vincenz, 1973 ; Vincenz and al., 1973 ; Dasgupta and Vincenz, 1975 ; Mc Donald and Van Horn, 1977 ; Gose and Swartz, 1977 ; Guja and Vincenz, 1978 ; Dasgupta, 1978 ; Hargraves and Skerlec, 1980 ; Skerlec and Hargraves, 1980 ; Stearn and al. 1982 ; Donald and Krushensky, 1983 ; Kerdraon, 1984 and Gose, 1985).

It can be clearly seen that :
- the northern Caribbean boundary exposes paleomagnetic vectors which imply a 80° counterclockwise rotation between the upper Cretaceous and the Miocene;
- the southern boundary of the Caribbean Plate is characterized by paleomagnetic vectors which indicate 90° of clockwise rotation since the upper Cretaceous.

In the Honduras, Gose and Swartz (1977), Gose (1985) suggest a polyphasic rotation, clockwise during the lower Cretaceous and counterclockwise between the upper Cretaceous and the Present.

The available data are in agreement with the kinematic model of the Caribbean Plate. This plate moves to the East and pushes to its boundaries the blocks (islands) which are to its front (Stephan, 1982). The curvature of the actual Lesser Antilles arc expresses perfectly this phenomenon and explains the observed clockwise rotations (in the South) and counterclockwise rotations (in the North).

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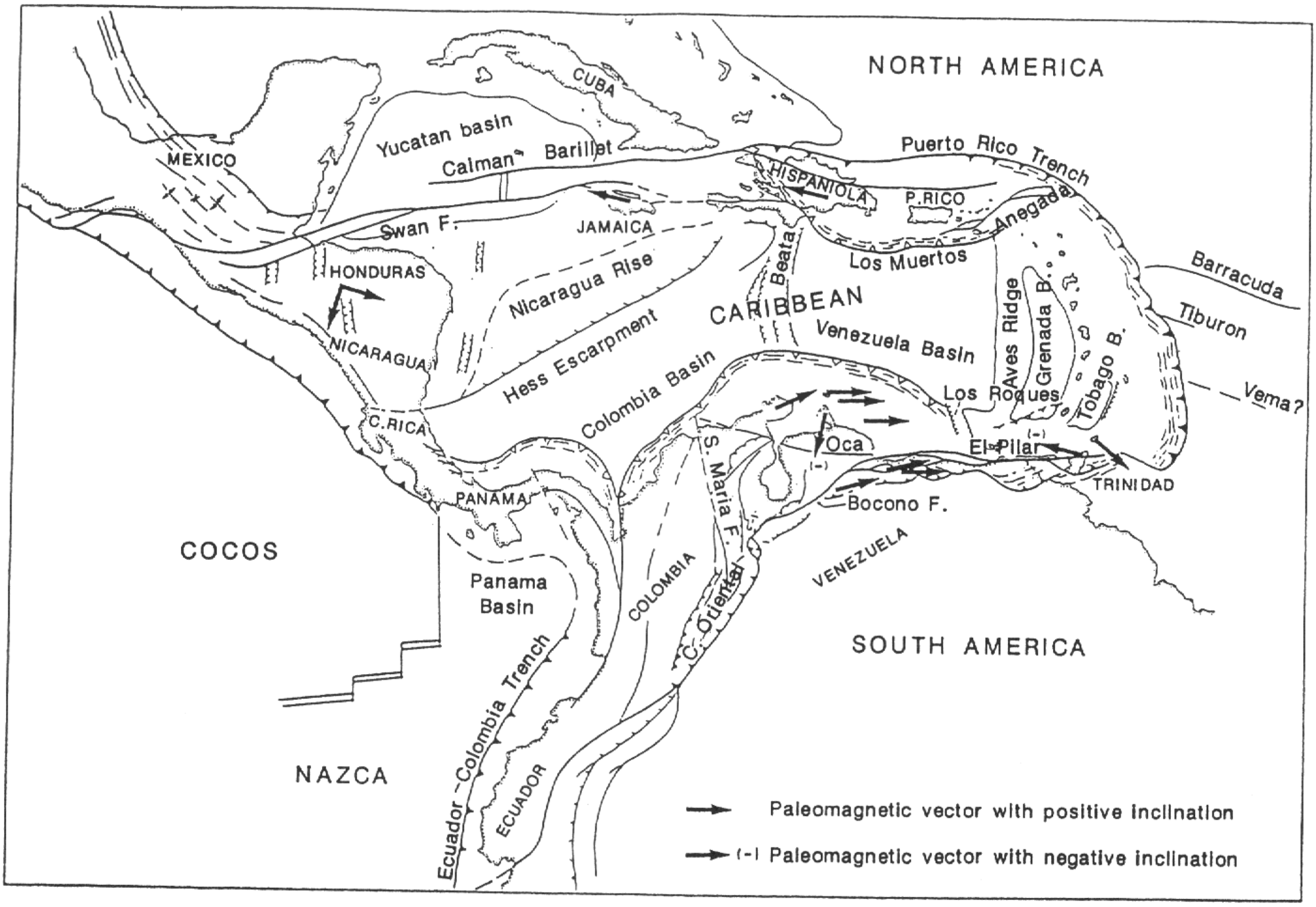


Fig. 1 : Paleomagnetic vectors indicating the tectonic rotations which have occured since the Cretaceous in the Caribbean geodynamic context;Data from various authors.

GEOLOGICAL BACKGROUND OF THE VENEZUELAN CARIBBEAN MOUNTAIN CHAIN

From east to west, the Caribbean mountain chain borders the margin of the South America. This chain is a stack of nappes and shows, from south to north (Stephan, 1977, 1982, 1985 ; Stephan and al., 1980 ; Beck, 1977, 1978, 1986; Santamaria and Schubert, 1974) :

- Paleocene-lower Eocene terrigenous flysch of the Piemontin nappe. This flysch overlays Cretaceous to Paleocene marine sequences.
- the Villa de Cura nappe which is essentially composed of metamorphised volcanic and sedimentary rocks, Coniacian conglomerates and limestones and a volcanic sequence dated with metamorphosed tuffs at 100 Ma (Piburn, 1967, in Skerlec and Hargraves, 1980).
- the Loma de Hierro-Siquisique ophiolitic nappe principally constituted of gabbros and peridotites with a dolerite complex and intruded by microgabbro sills. This unit is unconformably overlain by Maastrichtian sedimentary rocks ;
- the Tinaco-Tinaquillo nappe which is an igneometamorphic and ultramafic complex intruded by a 112 Ma old trondjemite (Martin Bellizzia, 1968 in Skerlec and Hargraves, 1980) and middle Albian sills and diabases. The complex is overlain by Turonian calcareous sediments.Paleocene-Eocene conglomerates, overlay unconformably the whole of the underlying rocks.
- the Coastal Fringe unit composed by eclogites, amphibolites and ultramafic rocks intruded in metatuffs and schists. The age of these rocks metamorphosed in green schist facies is upper Jurassic-lower Cretaceous.
- the Coastal Cordillera unit which is a detritic, calcareous and metamorphosed Jurassic-Cretaceous sequence. It is transgressive over a Precambrian and Paleozoic gneissic basement. Granodiorites (80 Ma, Santa Maria and Schubert, 1974) intrude the Coastal Cordillera unit.

PREVIOUS PALEOMAGNETIC DATA FROM VENEZUELA

All the following paleomagnetic data have been compiled in a synthetic review by Kerdraon (1984).

Caribbean Mountain chain (Skerlec and Hargraves, 1980).

The Villa de Cura nappe :
. site 8 : dykes of 100 Ma
. sites 9 and 10 : a 100 Ma ultramafic intrusion
. site 11 : upper Jurassic (?)-lower Cretaceous ultramafic El Chacao complex (Beck, 1983)
the Tinaco unit :
. site 6 : pre-upper Cretaceous ultramafic intrusions

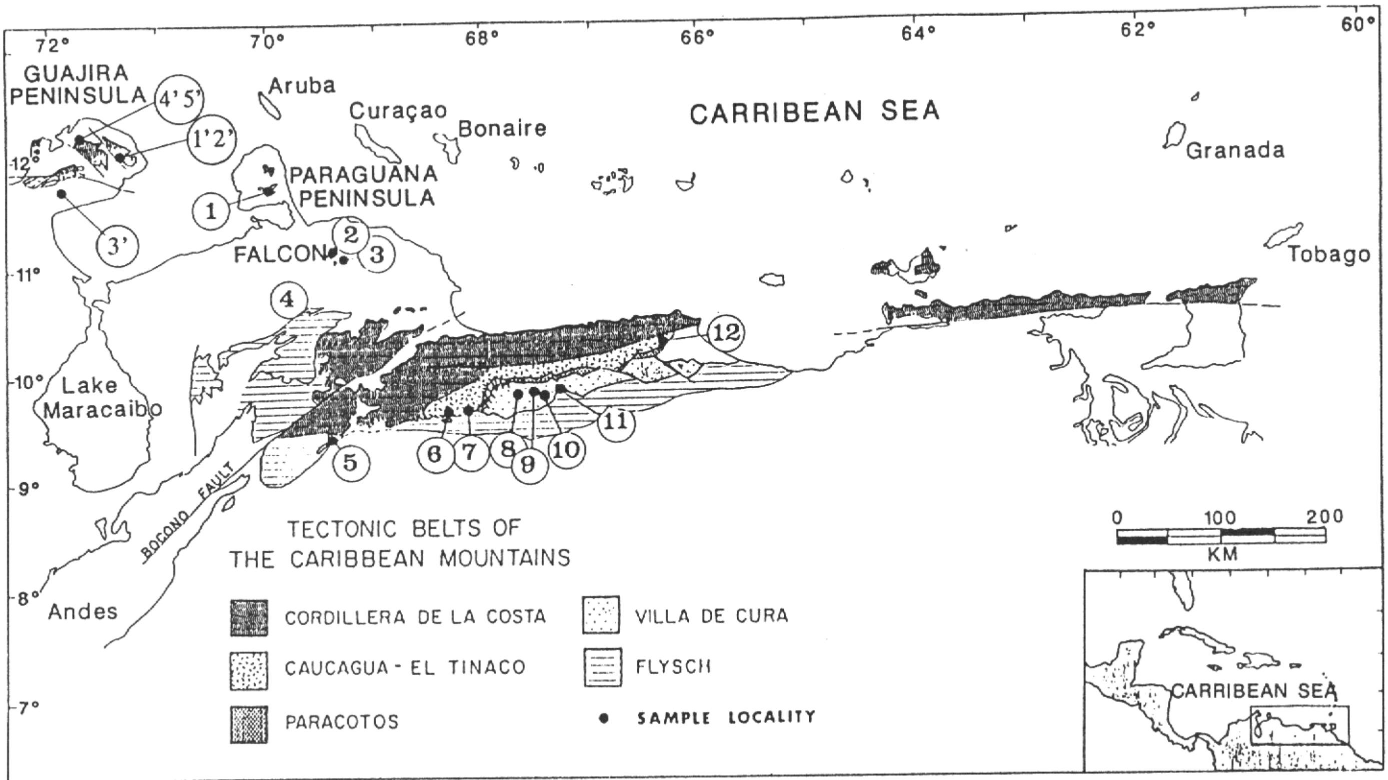


Fig. 2 : Location of the previous paleomagnetic studies (Skerlec and hargraves, 1980 ; Macdonald and Opdyke, 1972).

. site 12 : gabbros intruded in the Gonoropa volcanic rocks which overlay the pre-Mesozoic sequences of the Tinaco unit.

The Siquisique ophiolitic nappe :

. site 4 : gabbros with pyroxenous associated with serpentinites.

The Piemontin unit :

. site 5 : post Paleocene-lower Eocenous ultramafic intrusif (cerro Pelón).

The paleomagnetic results are rather scattered but they indicate a N90E general paleodeclination.

Falcon Basin Guajira and Paraguana Peninsula (Fig. 2).

Falcon Basin : (Skerlec and Hargraves, 1980)

The paleomagnetic studies concern Oligocene gabbroic and dioritic intrusions (site 2). The magnetization vectors indicate a 10° of clockwise rotation.

Paraguana Peninsula : (Skerlec and Hargraves, 1980)

The paleomagnetic data came from gabbros and volcanic rocks of the Santa Ana complex (site 1). The results do not indicate rotation since the lower Cretaceous.

The Guajira Peninsula : (Mac Donald and Opdyke, 1972)

. sites 1' and 2' : Sipana dioritic intrusion and dykes of 195 ±8 Ma.

. site 3' : Rhyodacite (La Teta lava) and diorite of Maruayan respectively of 95 to 120 Ma. and 120 ±4 Ma.

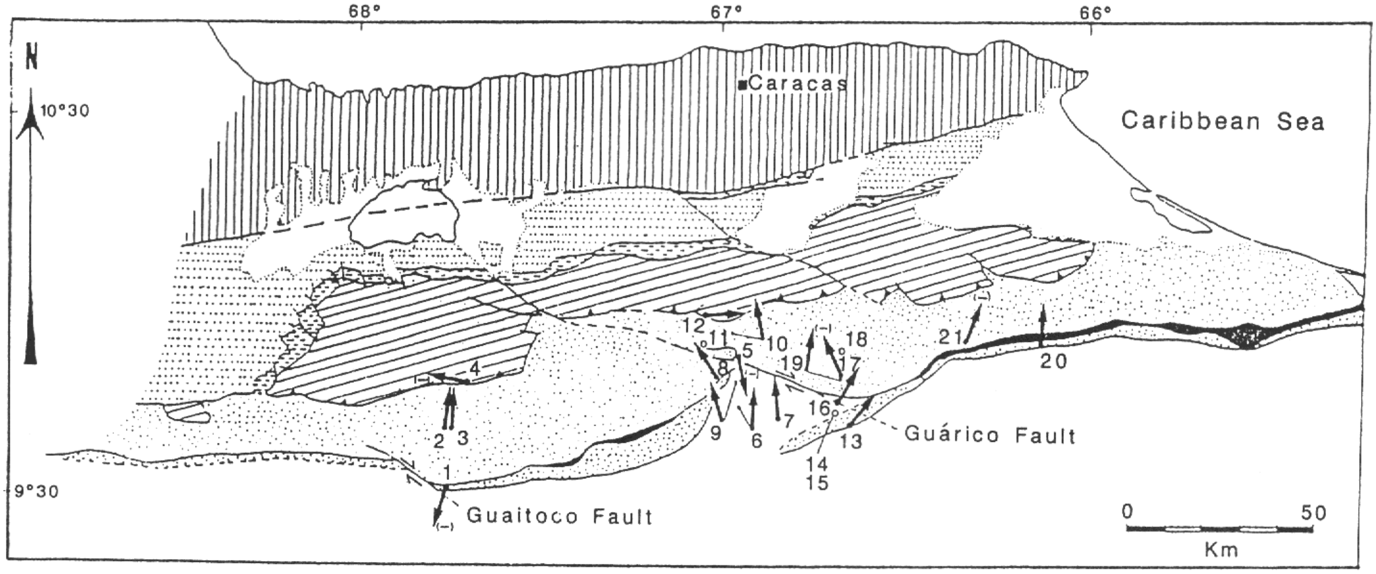
. sites 4' and 5' : Eocene Parashi diorite and dyke.

From the obtained results (Sipana diorites, Teta Lava and Maruayan diorites), the rotation could be estimated to 90° clockwise since the lower Cretaceous. It would have been about only 30° since the Eocene (Parashi diorite and dyke).

Conclusions on the previous paleomagnetic data

The paleomagnetic vector directions, issued from the Venezuelan allochthonous series, show a general 90° clockwise rotation in agreement with the Caribbean plate geodynamic model.

However, it is important to note that the obtained results concern principally the Cretaceous rocks of the southern Caribbean margin. It is more reasonable to consider a 90° clockwise rotation for the allochthonous Cretaceous terranes of the South caribbean region rather than for this whole margin. In this way, we shall see that the Cerro Pelón is not an intrusive in the Piemontin nappe.



Paleomagnetic vector with positive inclination

(–) Paleomagnetic vector with negative inclination

18 Site with incoherent paleomagnetic data

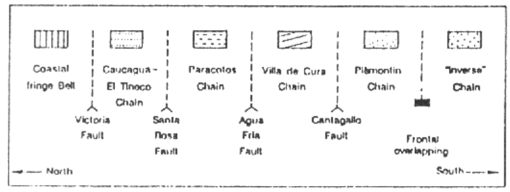


Fig. 3 : Location of the paleomagnetic studies and display of the paleomagnetic vector orientations (this study).

NEW PALEOMAGNETIC STUDY OF THE CARIBBEAN CHAIN PIEMONTIN NAPPE BETWEEN SAN FRANCISCO DE TIZNADOS AND TAGUAY.

The new study of the Caribbean chain front (Blin, 1989) is centered on the Piemontin nappe in order to test possible rotations that affect it, particularly near the Guaitoco and Guárico dextral strike-slip faults.

Sampling was done in the Villa de Cura nappe and in the Oligo-Miocene sandstones of the Quebradón Formation to compare their movements. On the whole 21 sites, 171 samples have been analysed for this study.

Sampling

The figure 3 indicates the position of the studied sites in several unities :
- the Oligo-Miocene sandstones (Fm. Quebradón) : sites 1, 6, 7, 9, 13, 14, 15, 16 and 20;
- the Piemontin nappe : the numerous klippen have permitted to sample the flysch of the Guárico Formation (sites 5, 8, 10, 18 and 21) and the pelites and limestones of the San Antonio Formation (sites 2, 3, 11, 17 and 19);
- the Villa de Cura nappe : the sandstones and microconglomerates with volcanic fragments have been sampled (sites 4 and 12).

For this study, the samples were collected with a thermic portable drill. When it was possible, the oriented samples were taken on the same stratum and in an area of less than a square meter at each site. All the samples therefore have the same magnetic history which gives more credit to the Fisher statistics.

Laboratory Treatment

Natural Remanent Magnetization (NRM) characteristics are measured using a cryogenic magnetometer. To isolate characteristic components of the NRM, stepwise thermal demagnetization procedures which are more effective on the sedimentary rocks, were done up to 480° C.

Results

For all the samples, the demagnetization results are plotted on Zijderveld diagrams and stereograms. We have chosen the demagnetization step the most significant of the primary magnetization. The Fisher statistics have provided the average declination and inclination for each site, after the necessary dip correction. The results are summarized in the Tables 1, 2, 3 and 4 and in Figure 4

Remarks :

. site 1 : Samples 7,8 and 9 are not used because they were collected from a stratum different from the others and not well situated in stratigraphic column.
. site 2 : The sample 9 is insufficiently stable. It is not considered in the average paleovector.
. site 3 : Samples 1, 3, 4 and 5 are not considered because of the bad quality of their Zijderveld diagrams.
. site 8 : The Zijderveld diagrams and the stereograms incoherence do not allow to keep the results of the samples 6, 7 and 8.
. site 12 : the Zijderveld diagrams and the stereograms incoherence of the samples 1, 3 and 4, and the too high inclination of the paleovector of the sample 5, do not allow to keep these

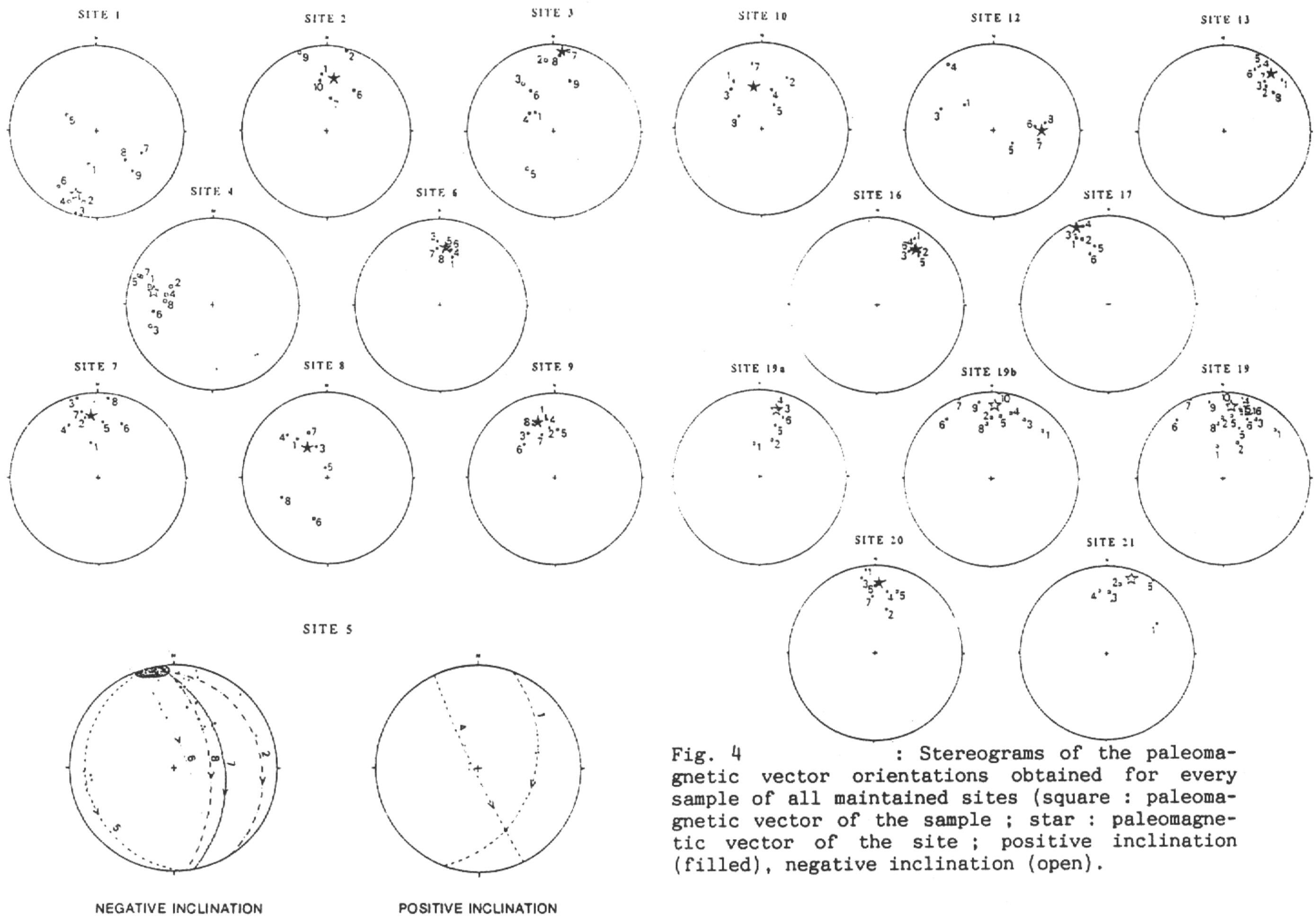


Fig. 4 : Stereograms of the paleomagnetic vector orientations obtained for every sample of all maintained sites (square : paleomagnetic vector of the sample ; star : paleomagnetic vector of the site ; positive inclination (filled), negative inclination (open).

samples for the calculation of the site 12 average direction.

. sites 11, 14, 15 and 18 : The demagnetization curves, the stereograms and the Zijderveld diagrams are not good enough. Under these circumstances it is better to ignore these sites for our study.

Discussion

The figure 3 synthetizes the paleomagnetic results obtained for all sites and it is possible to compare them with the regional geology. We note :

- a 90° clockwise rotation of the Villa de Cura nappe indicated by the East (positive) or West (negative) declinations of the magnetic paleovectors at sites 4 and 12.

- no general rotation in the Oligo-Miocene sandstones of the Quebradón Formation that can explain the North (positive) and South (negative) paleomagnetic vector declinations at sites 1, 6, 7, 9, 13, 16 and 20.

- a few degrees generally counter-clockwise rotation for the Piemontin nappe at sites 2, 3, 5, 8, 10, 17, 19 and 21.

We suggest that these paleomagnetic results indicate that the Villa de Cura nappe was a North-South oriented island arc which rotated over 90° clockwise before overthrusting the Ghuyana craton. These data are in agreement with those of Skerlec and Hargraves (1980).

In Oligo-Miocene sandstones, there are no significative rotations as would be expected by their autochthonous (or parautochthonous) character.

The Piemontin nappe does not show generally large rotations, but up to 30° clockwise occur locally near dextral strike-slip faults. These results are contrary to those of Skerlec and Hargraves (1980) who conclude to a 90° clockwise rotation for the Piemontin nappe from their study of the Cerro Pelón region. A geological study suggests that this massif is a klippe of the Villa de Cura paleoarc (Blin, 1989) and that it cannot be used as a movement marker from the Piemontin nappe.

In detail, we can observe structural effects on the paleomagnetic vector orientations in the Oligo-Miocene sandstones of the Piemontin nappe (fig. 3) :

- the dextral Guaitoco fault may be responsible for the 20° clockwise rotation of the site 1 paleomagnetic vector (table 1).

I

SAMPLES	Site 1 (long.=-67°37,58' / lat.=9°37,05') decl.	incl.	step °C	Site 2 (long.=-67°35,58' / lat.=9°28,86') decl.	incl.	step °C	Site 3 (long.=-67°35,58' / lat.=9°38,96') decl.	incl.	step °C	Site 4 (long.=-67°31,65' / lat.=9°46,68') decl.	incl.	step °C
1	194.3	-47.3	120	355.5	22.5	200	315.5	55.5	200	287	-14.8	300
2	191.7	-10.4	30	14.5	0.7	200	354.1	-11.5	200	292.9	-34.3	300
3	195	1.7	150	/	/	/	327.5	-2.4	300	251.6	-15	300
4	202.5	-47.5	200	/	/	/	306.2	50.8	200	282.6	-31.9	380
5	299.3	-46.6	300	/	/	/	217.1	-33.3	380	292	-5.7	350
6	215.3	-14.7	300	33.1	30.5	300	329.8	33.4	300	262.8	20.7	350
7	116.4	30.5	380	6.5	47.1	200	11.1	-2.9	380	292.1	-7.3	380
8	138	26.8	430	/	/	/	5.8	6.9	350	275.2	-31.8	380
9	135.5	40.5	300	340.1	-1.9	200	18.1	27.2	200			
10				352.1	28.7	200						
decl. moy.	200.1			3.2			7.0			282.0		
incl. moy.	-15.6			26.7			4.9			-20.6		
K	15.1			13.4			17.7			19.1		
α_{95}	20.2	N.5 (sam. 1,2,3,4,6)		21.6	N.5 (sam. 1,2,6,7,10)		22.4	N.4 (sam. 2,7,8,9)		14.1	N.7 (sam. 1,2,3,4,5,7,8)	

Rq : Site 5 : long.=-66°53,88' / lat.=9°51,35' **Decl : 165° Incl : 4°**

III

SAMPLES	Site 10 (long.=-66°54,58' / lat.=9°54,08') decl.	incl.	step °C	Site 12 (long.=-66°57,28' / lat.=9°56,00') decl.	incl.	step °C	Site 13 (long.=-66°37,33' / lat.=9°43,28') decl.	incl.	step °C	Site 16 (long.=-66°39,43' / lat.=9°47,28') decl.	incl.	step °C
1	329.6	25.1	430	311.5	43.1	150	49.1	6.1	200	14.8	33.1	300
2	26.3	23.2	150	/	/	/	43.7	18.5	200	19.3	43.9	350
3	321.4	29.2	350	292.2	24.5	350	39.6	16.2	200	7.1	41.6	350
4	14	40.1	300	326.1	-5.4	200	34.9	-8	200	15.3	39.8	350
5	26.2	54.9	300	125.6	60.6	300.	28.8	-3.5	200	19.0	46.8	350
6	/	/	/	85.4	38.8	350	27	12.2	200	10.3	40.2	300
7	350.9	14.6	300	101.2	34.2	300	37.4	9.8	200			
8	294.5	54.9	300	80.1	27.9	430	52.4	18.4	200			
9												
10												
decl. moy.	350.0			88.6			39.0			34.7		
incl. moy.	38.5			31.2			8.2			14.1		
K	7.1			67.7			33.2			192.0		
α_{95}	24.3	N:7		15.0	N.3 (sam. 6,7,8)		9.7	N:8		4.8	N:6	

.. Before bedding correction (N170, 45 W)

II

SAMPLES	Site 6 (long.=-66°54,21' / lat.=9°45,56') decl.	incl.	step °C	Site 7 (long.=-66°48,73' / lat.=9°45,01') decl.	incl.	step °C	Site 8 (long.=-66°55,65' / lat.=9°48,83') decl.	incl.	step °C	Site 9 (long.=-66°54,21' / lat.=9°48,81') decl.	incl.	step °C
1	14.8	30.5	480	348.5	44.9	200	322.4	30.7	200	352	18	200
2	/	/	/	348.3	19.1	200	/	/	/	354.4	29.4	150
3	357.3	16.8	480	346.2	2	200	340	48.2	200	329.7	27.6	200
4	12.1	23.1	480	331.5	19.9	350	316.5	21.3	200	352	21.1	200
5	5.7	21.7	480	4.8	24	350	346.4	76.5	200	3.8	31 *	200
6	11.9	21.8	480	23	20.8	200	198.9	-37.3	200	317.8	34.2 *	150
7	356.3	22.7	480	346.3	13.4	300	337.7	-31.3	200	343.6	34.1 *	300
8	5.5	24.4	480	7	3.4	150	247.8	29.3	200	338.4	22	300
9												
10												
decl. moy.	6.3			354.4			326.7			344.2		
incl. moy.	23.1			18.9			44.4			21.4		
K	109.2			16.2			10.0			11.5		
α_{95}	5.8	N:7		14.1	N:8		30.4	N:4 (3,4,5,1)		17.0	N:8	

* Computed with Zijderveld diagram

IV

SAMPLES	Site 17 (long.=-66°54,40' / lat.=9°49,66') decl.	incl.	step °C	Site 19a (long.=-66°28,92' lat.=9°49,30') decl.	incl.	19a + 19b	Site 19b (long.=-66°28,55' lat.=9°49,56') decl.	incl.	Site 20 (long.=-66°07,25' lat.=9°56,28') decl.	incl.	Site 21 (long.=-66°18,00' lat.=9°55,89') decl.	incl.
1	344.1	40	150	350	-48		47	-11	353	1.98	60	22
2	337.8	16.6	300	22	-42		0	-20	14	34.19	11	-12
3	336.9	24	300	15	-12		29	-14	349	6.87	3	-20
4	350.6	31.1	300	14	-11		16	-14	11	18.67	353	-18
5	8.3	43.8	350	18	27		3	-18	20	-16	32	0
6	339.7	28.3	350	22	17		322	8	0.	14		
7							337	0	357	23		
8							355	-25				
9							350	6				
10							4	0				
decl. moy.	337.5			14.4		6.9	2.6		3.0		19.2	
incl. moy.	1.9			-11.6		-10.4	-9.5		12.0		-6.2	
K	33.6			6.6		8.4	9.4		17.0		6.9	
α_{95}	11.7	N.6		27.9	N.6	13.4	16.5	N.10	15.0	N:7	31.1	N.5

.. Before bedding correction (N30, 38 W)

Table 1, 2, 3 and 4 : Paleomagnetic results (this study).

- the dextral displacement along the Guárico fault could explain the 35-40° rotation observed to the sites 13 and 16 (table 3).

For the sites far from this strike-slip fault, the paleomagnetic vector retains a North-South orientation and testifies to the absence of tectonic movements in these localities.

The site 13 displays a clockwise rotation identical to that of site 16. The evidence of rotation is displayed by the curvature of folds in the Oligo-miocene rocks near the Guarico fault. The geologic map of Venezuela (Ministerio de Energía y Minas, 1976, 1/500000) shows that these folds, originally oriented N60-70E, to the west of the Guárico fault, are oriented East-West direction near the fault. The lack of correspondence of the site 14 and 15 data could result from the position of these sites in a fault zone. The clockwise rotations are thus due to the movement along the Guárico fault (site 16) and to the Oligo-Miocene folds deformation under the Piemontin nappe progression to the South (site 13).
The more or less North-South declinations of the sites 2, 3, 5, 8, 10, 17, 19 and 21 paleovectors indicate that, on the whole, the Piemontin nappe does not significantly rotate within the precision level given by the $\alpha95$ value, radius of circle of confidence (Fisher, 1953) .

Nevertheless, taking the paleomagnetic declinations of the sites 5, 8, 17 and 19 (keeping the average vector of these two later sites), it can be observed that the paleovectors are more or less perpendicular to the Piemontin nappe meridional boundary. In contrast, in its median part (sites 2, 3 and 10) the vectors remain a North-South orientation. This scheme could represent an image of nappe which flows and where the force lines keep perpendicular to its front. A similar model explains the Hellenic arc structure : the deformation pattern of Aegean zone (Angelier and Le Pichon, 1980) justifies the paleomagnetic declinations obtained by Laj and al. (1982) and Freeman (1983).
Remark :
it is possible that the site 5 had recorded the Guárico fault dextral movement but the demagnetization circle method (used for this site) does not give any $\alpha95$ value. Then, for our discussion, we have kept the average North-South paleomagnetic vector orientation in this site.

CONCLUSION

These results, associated to the field data, confirm that the Villa de Cura nappe was a north-south oriented island arc rotated 90° clockwise since Cretaceous time, in agreement with the models of Caribbean geodynamic evolution proposed by various authors (Pindell and Dewey, 1982 ; Stéphan, 1982 ; Beck, 1986). In contrast, the Piemontin nappe did not rotate and has moved with an orientation similar to its original position. But near the southern limit of the nappe, the paleomagnetic declinations are often more or less perpendicular to the front and may be due to its southward differential progression, further some deflection may be induced by the Guarico fault. Finally, the autochthonous Oligo-Miocene sandstones, to the south of the Piemontin nappe, do not show rotations excepted locally near the Guárico and Guaitoco dextral faults.

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